

... to the Commissioner of Patents and Trademarks:

Transmitted herewith for filing is the Utility Design Plant patent application of:

Inventor(s) Chester M. Dacres, Ph.D., P.E.

Title of invention: Portable Hand-held In-situ Electrochemical Sensor for Evaluating Corrosion and Adhesion on Coated and Uncoated Metal Structures

Enclosed are the following items:

- A. Duplicate copies of this Patent Application Transmittal Form.
- B. Sheet(s) of informal formal drawings.
- C. Page(s) of specification.
- D. Page(s) of claims.
- E. 1 Page(s) of abstract.
- F. 1 Declaration (Signed) X (Unsigned) _____
- G. A Power of Attorney executed by the [] Inventor(s) [] Assignee.
- H. An assignment transmittal letter
- I. X A verified statement to establish Small Entity status under 37 CFR 1.9 and 37 CFR 1.27
- J. An Information Disclosure Statement.
- K. A list of references (Form PTO-1449)
- L. Copies of references
- M. Preliminary Amendment
- N. Postcard
- O. Other (specify) _____

CLAIMS AS FILED

BASIC FILING FEE:	SMALL ENTITY		OTHER THAN SMALL ENTITY	
	<input checked="" type="checkbox"/> Utility	<u>\$355</u>	or	<u>\$710</u>
<input type="checkbox"/> Design	<u>\$145</u>	or	<u>\$290</u>	<u>\$ _____</u>
<input type="checkbox"/> Plant	<u>\$260</u>	or	<u>\$480</u>	<u>\$ _____</u>
TOTAL CLAIMS <u>- 20 -</u>	<u>X \$ 11</u>	or	<u>X \$ 22</u>	<u>= \$ _____</u>
INDEPENDENT CLAIMS <u>- 3 -</u>	<u>X \$.37</u>	or	<u>X \$.74</u>	<u>= \$ _____</u>
MULTIPLE DEPENDENT CLAIMS PRESENT	<u>+ \$115</u>	or	<u>+ \$230</u>	<u>= \$ _____</u>
RECORDING FEE FOR ASSIGNMENT (\$40.00)				<u>\$ _____</u>
TOTAL FILING FEE:				<u>\$ _____</u>

The Commissioner is hereby authorized to charge and credit Deposit Account No. _____ as described below:

- Charge the total filing fee of \$_____.
- Charge any additional filing fees as required under 37 CFR 1.16 and 1.17.
- Credit any overpayment.
- Charge the issue fee required under 37 CFR 1.18 at the time of mailing of the Notice of Allowance, pursuant to 37 CFR 1.311(b).

Claim for Priority Under 35 U.S.C. §120:

- The benefit under 35 U.S.C. §120 is hereby claimed from the following United States application:

Claim for Priority Under 35 U.S.C. §119:

A

- The benefit of priority under 35 U.S.C. §119 is hereby claimed from the following foreign application:

Please address all correspondence in connection with this application to:

Dr. Chester M. Dacres, P.E.

President

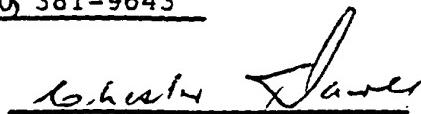
DACCO SCI, INC.

10260 Old Columbia Road

Columbia, MD 21046

Telephone: 410 381-9475

Faxsimile: 410 381-9643


Signature of Applicant or Attorney

Registration No.: _____

Date: June 8, 1998

DSI

DACCO SCI, INC.

CORROSION ENGINEERING-MATERIALS TECHNOLOGY-ELECTROCHEMISTRY

**10260 OLD COLUMBIA ROAD, COLUMBIA, MD 21046
BALT. (410) 381-9475 • DC (301) 596-7019 • FAX (410) 381-9643**

June 8, 1998

U.S. DEPARTMENT OF COMMERCE
PATENT & TRADEMARK OFFICE
Attention: Application Branch
Assistant Secretary and Commissioner
of Patents and Trademarks
Washington, DC 20231

RE: PROVISIONAL APPLICATION FOR PATENT

Dear Sir

Pursuant to the directives of 37 CFR § 1.53(b)(2), I hereby request that the attached provisional application be filed as follows:

For: **Portable, Hand-held, In-Situ Electrochemical Sensor for Evaluating Corrosion and Adhesion on Coated and Uncoated Metal Structures**

Name of first Inventor: **Guy Donald Davis, Ph.D.**
Residence Address: **1 South Beechwood Avenue, Baltimore, MD 21228**

Name of second Inventor: **Chester Malcolm Dacres, Ph.D., P.E.**
Residence Address: **5092 Jericho Road, Columbia, Maryland 21044**

Enclosed are the Following Supporting Documentation:

- (X) Specification in pages 1 to 14.
- (X) 5 Sheets of Drawings.
- (X) A check in the amount of \$375.00 to cover the filing fee is enclosed.

The attached provisional application contains the necessary specification, background of the invention, summary of the invention, claims and an abstract of the disclosure. Furthermore, the invention was NOT made by an agency of the United States Government.

Page Two
Letter to Assistant Secretary and
Commissioner of Patents and Trademarks
June 5, 1998

Should you have any questions, please do not hesitate to contact me at (410) 381-9475. All correspondence may be sent to my attention at the following address: DACCO SCI, INC., 10260 Old Columbia Road, Columbia, MD 21046. Thank you for your attention in this matter.

Respectfully Submitted

Respectfully Submitted


**Chester M. Dacres, Ph.D., P.E.
President**

CMD/kdd

1

2 **Portable, Hand-held, *In-Situ* Electrochemical Sensor**

3 **for Evaluating Corrosion and Adhesion on Coated and Uncoated Metal Structures**

4

5 **BACKGROUND OF THE INVENTION**

6 1. *Field of the Invention*

7 The present invention relates to a portable, hand-held and nondestructive corrosion sensing
8 device for detecting the early stages of metal and coating degradation and electrochemical corrosion.
9 More specifically, the present invention relates to a portable corrosion sensor which is utilized under
10 field (actual, environmental or *in situ*) conditions in detecting coating degradation and
11 electrochemical corrosion of both small and large coated (painted) and uncoated metal structures,
12 thereby permitting detection of coating and metal degradation and electrochemical corrosion well
13 before serious deterioration of the material or structure has occurred.

14 2. *Prior Art*

15 A major goal in the electrochemical field has long been to create a sensor which could be
16 utilized in field or service conditions to detect corrosion and adhesion on metal structures of any
17 size before significant degradation has occurred. Evaluation of materials and coatings and the
18 determination or prediction of corrosion performance of both painted and uncoated metal
19 structures or specimens under ambient field or service conditions has traditionally involved visual
20 comparisons which are subjective and require blistering, rusting, or other advanced stages of
21 degradation. The use of laboratory techniques, such as electrochemical impedance spectroscopy
22 (EIS, also known as AC impedance), which has been used to understand and predict corrosion
23 performance during immersion exposures in different electrolytes was limited to small structures

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2 or witness specimens that could be immersed, small sections of material cut from large
3 structures, or attachment to the structure of a clamp-on liquid cell in which a liquid or semi-
4 liquid electrolyte and remote counter and reference electrodes were contained.

5 Inspection of a large structure using conventional EIS methodologies required complete
6 immersion or use of a clamp-on cell. Such cells would be filled with a liquid or semi-liquid
7 electrolyte (e.g., Kihira *et al.*, U.S. Patent 4,806,849; and Kazami *et al.*, U.S. Patent 4,861,453)
8 or a spongy medium impregnated with a liquid electrolyte (e.g., Kondou *et al.*, U.S. Patent
9 5,221,893) with remote electrodes immersed in the electrolyte or in intimate contact with the
10 electrolyte-impregnated sponge. These cells required an accessible, flat, smooth, and horizontal
11 area. The set-up was considered to be time consuming and had to be performed for each
12 measurement. Corrosion was detected only directly under the cell and use of the cell actually
13 caused artifactual damage to the coating in many instances because of exposure to the electrolyte
14 during measurement.
15

16 Davis *et al.*, U.S. Patent Application No. 08/724,753, recently taught a painted electrode
17 sensor which eliminates many of the problems discussed above. The actual structure is being
18 inspected without exposure to an extrinsic electrolyte. Measurements are possible under most
19 natural or accelerated conditions and material and coating degradation are detectable from the
20 very early stages. However, the Davis *et al.*, sensor requires an electrode to be permanently
21 painted onto the structure and is time-consuming, because of all of the fabrication steps which
22 must be completed. It is not suitable for structures in which appearance or aerodynamics
23 preclude an attached sensor. The sensor can induce artifactual damage in a small class of

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materials, primarily porous coatings.

Presently, there is no portable, hand-held corrosion sensing device for early detection of electrochemical corrosion, metal and coating degradation which can evaluate degradation on structures or material of any size, under *in situ* or actual conditions, as well as under aggressive corrosive conditions, and which requires no permanent attachment.

SUMMARY OF THE INVENTION

The principal objective of the present invention is to provide a portable, hand-held and nondestructive corrosion sensing device which is utilized under field (actual, environmental or *in situ*) conditions in detecting coating degradation and electrochemical corrosion of both small and large coated (painted) and uncoated metal structures, thereby permitting detection of coating and metal degradation and electrochemical corrosion well before serious deterioration of the material or structure has occurred. The present invention allows for broad applicability, flexibility in utilizing the sensor in various environments without structural compromise and/or the ability to inspect and evaluate corrosion of the actual structure, regardless of the size of the structure.

The foregoing objectives can be accomplished utilizing the present invention as a portable, hand-held and nondestructive corrosion sensing device providing an *in situ* sensor for producing an output correlative to an identifiable impedance spectrum (i.e., the impedance magnitude and phase as a function of the frequency of the applied voltage, created utilizing AC Impedance or Electrochemical Impedance Spectroscopy (EIS). The preferred embodiment of the invention is a portable, hand-held and nondestructive apparatus, comprising a pen-like device

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2 which consists of a metal tip which serves both as a counter and reference electrode. The metal
3 structure being tested, which either may be coated or uncoated, serves as the working electrode.
4 This two electrode sensing device measures differences in impedance spectra which are
5 responsive to atmospheric, water uptake, incubation, and corrosion; utilizing, the metal tip as the
6 counter and reference electrode, applying a small electrical voltage between the metallic
7 substrate of the structure, which serves as the working electrode, and the counter/reference
8 electrode and measuring the resulting current based upon the applied voltage between the
9 electrodes. The portable, hand-held *in situ* corrosion sensor contemplated in the present
10 invention is pressed against the top coat during inspection. The present invention readily detects
11 the early stages of interfacial degradation well before any visual indication of corrosion appears,
12 as well as the ability to detect, quantify and monitor coating and metal degradation from its
13 earliest stages under both laboratory and field conditions.

14 **BRIEF DESCRIPTION OF THE DRAWINGS**
15

16 Fig. 1 is an impedance spectrum for painted aluminum following immersion for different
17 periods of salt water exposure.

18 Fig. 2 is a diagrammatic representation of the pen-like sensing device with attached metal
19 tip 2, that serves as the counter and reference electrode. The cable which is attached to 2, is
20 connected to the potentiostat. The working electrode 1, is the coated metal being tested and
21 connected to the potentiostat with an attached wire 3.

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Fig. 3 is a graphic representation of impedance spectra of epoxy-polyimide painted aluminum with and without a scratched defect using both a conventional three-electrode measurement and measurements made using three different embodiments of the present invention.

Fig. 4 is a graphic representation of vinyl-coated steel panels exposed to ambient fresh water obtained using the present invention.

Fig. 5 is impedance spectra for a painted aluminum specimen with a scratch to simulate a coating defect.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention provides a portable, hand-held, in-situ electrochemical sensor capable of detecting and monitoring corrosion of an actual structure from the earliest stages of deterioration. The sensor utilizes electrochemical impedance spectroscopy (EIS) for investigating corrosion and coating degradation.

Referring to the drawings, Fig. 1 is a plot of an impedance spectrum for painted aluminum following immersion for different periods of salt water exposure. The figure shows that initially the coated metal demonstrates capacitive behavior with very high impedance at low frequencies. As the coating degrades during immersion, its resistance decreases and the impedance become independent of frequency at low frequencies.

Fig. 2 is a drawing of a portable hand-held in-situ sensor with a metal tip 2, which acts as a reference and counter electrode. 2 is encased in a nonconductive plastic shield in the form of a pen-like holder for easy grasping in order to hold the tip of the electrode 2 onto the working painted metal 1 that is being tested. A cable is attached to the top of the pen-like electrode 2, to facilitate an easy electrical connection to a potentiostat. The working electrode 1, has a cable attached 3, for electrical connection to the potentiostat.

Fig. 3 is a series of impedance spectra of epoxy-polyamide panted aluminum with and without a scratch defect. Each of the three variation of the hand-held probe gives results very similar to the conventional three-electrode measurements. Each measurement very clearly reflects the presence of a gross defect such as a scratch.

Fig. 4 is a series of impedance spectra of vinyl-coated steel panels exposed to ambient fresh water for excellent condition even after 22 years of exposure; others were severely deteriorated even after one year. The correlation using the portable, hand-held in-situ electrochemical sensor is excellent. The coatings that appeared in excellent condition exhibited very high impedance with predominately capacitive behavior. In contrast, those coatings that were in poor condition with numerous blisters or rusty areas had very low impedance and mostly resistive behavior.

Fig. 5 is a series of impedance spectra for a painted aluminum specimen with a scratch to simulate a coating defect. As the portable, hand-held, in-situ sensor was moved further from the defect, a plateau region at intermediate frequencies appears and corresponds to a conduction

path along the surface.

We claim:

1. A method for the early detection of electrochemical corrosion, metal and coating degradation utilizing an inexpensive, portable, hand-held, and nondestructive corrosion sensor, for detection of corrosion of both small and large coated (painted) and uncoated metal structures, under field (actual, environmental or *in situ*) conditions, comprising the steps of:

(a) providing a portable, hand-held sensor for producing an output correlative to an identifiable impedance spectrum (i.e., the impedance magnitude and phase as a function of the frequency of the applied voltage, created utilizing AC Impedance or Electrochemical Impedance Spectroscopy (EIS)) comprising a pen-like device which consists of a metal tip which serves both as a counter and reference electrode responsive to atmospheric, water uptake, incubation, and corrosion which produce differences in impedance spectra, eliminating the need for a remote or counter electrode by electrolyte immersion; and utilizing, as the working electrode, the metal structure being tested, which either may be coated or uncoated;

(b) utilizing the sensor, which may be either straight in structural configuration (in the form of a pen) or bent in a curved or angled fashion to achieve better access through small openings, as the counter or reference electrode and pressing the metal tip of the sensor against the top coat of the metallic structure to be tested, a small electrical voltage is applied between the metallic substrate of the structure, which serves as the working electrode, and the pen-like sensor, and measuring the resulting current based upon the applied voltage between the

electrodes;

(c) controlling the detection area of the sensor by wetting the surface of the structure with water or other electrolyte allowing the sensor to detect corrosion or coating defects away from the sensor wherever the structure is wet.

(d) converting an analog signal indicative of the measured current to a corresponding ac impedance signal;

(e) providing a potentiostat's microcomputer with an operational program representative of a functional expression which correlates to distinctive impedance signatures; and

(f) converting the impedance spectrum as a function of accelerated exposure and interpreting the said spectrum to determine the stage of corrosion the metal and/or coating has experienced.

2. An apparatus for detection of metal and coating degradation of any metallic structure under field (actual, environmental or *in situ*) conditions, based on an identifiable impedance spectrum (i.e., the impedance magnitude and phase as a function of the frequency of the applied voltage created utilizing ac impedance or Electrochemical Impedance Spectroscopy (EIS)) comprising:

(a) means for measuring impedance spectra by applying electrical voltage between the metallic substrate of the structure as a working electrode and a counter or reference

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2 electrode comprising a pen-like device consisting of a metal tip and measuring the resulting small
3 electrical current based upon the applied voltage between the electrodes;

(b) means for converting an analog signal indicative of the measured current to a corresponding ac impedance signal;

(c) a potentiostat's microcomputer with an operational program representative of a functional expression which correlates to distinctive impedance spectra; and

(d) means for converting the impedance spectrum as a function of accelerated exposure and interpreting the said spectrum to determine the stage of corrosion the metal and/or coating has experienced.

ABSTRACT OF THE DISCLOSURE

A hand-held corrosion sensor is described that uses electrochemical impedance spectroscopy (EIS, also known as AC impedance) to detect coating degradation and corrosion of coated and uncoated metals. The hand-held sensor is pressed against the surface of the structure or specimen to be inspected. An EIS spectrum can then be obtained in the field or under arbitrary conditions and the degree of coating or material degradation can be determined from the resultant spectrum. There are no restrictions on the configuration of the structure being inspected. The area of detection is controlled by controlling the extent and degree of wetness of the surface. A dry surface will provide a localized measurement; a wet surface will allow inspection of the wetted area.

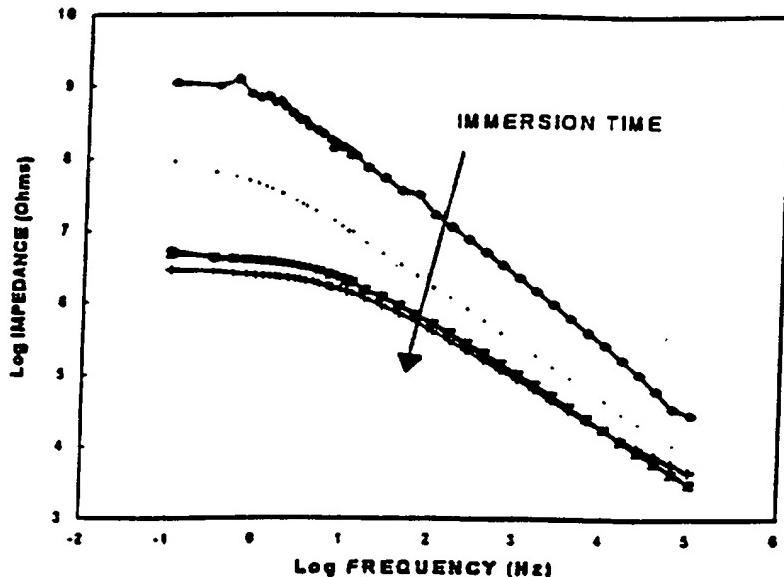
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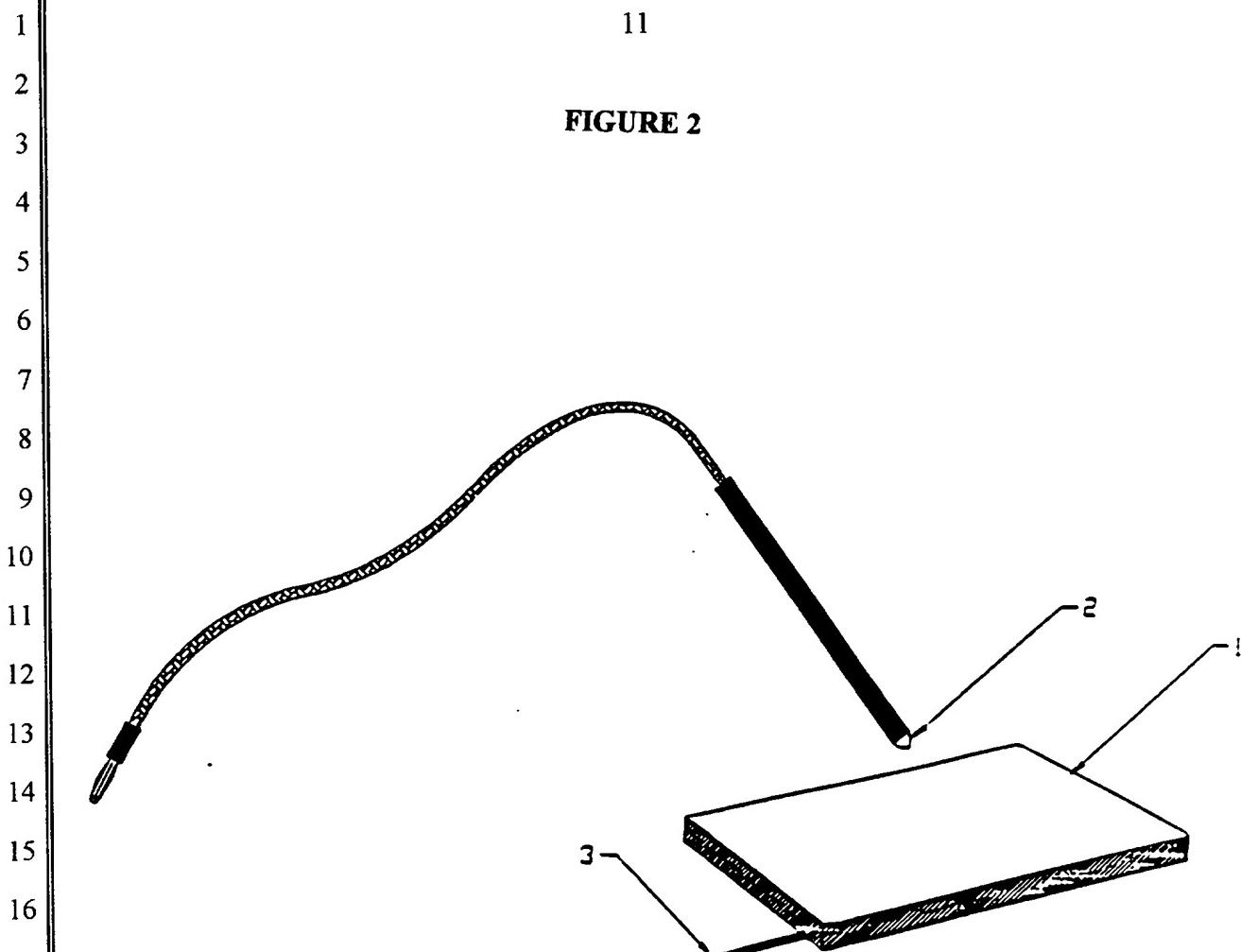
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FIGURE 1



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FIGURE 2

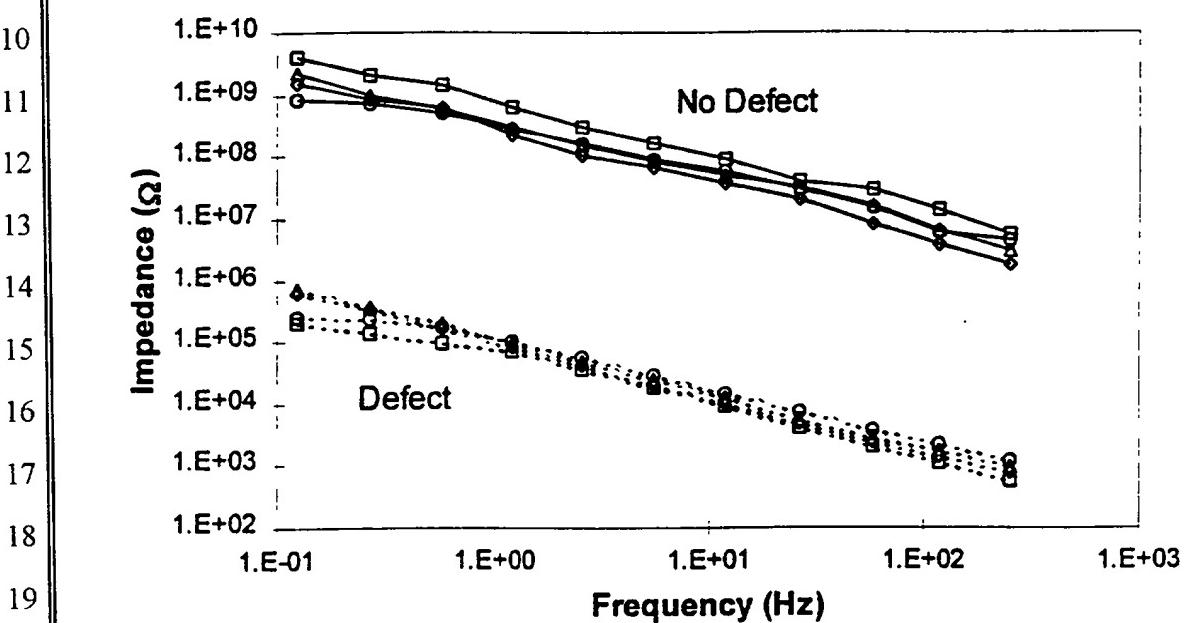
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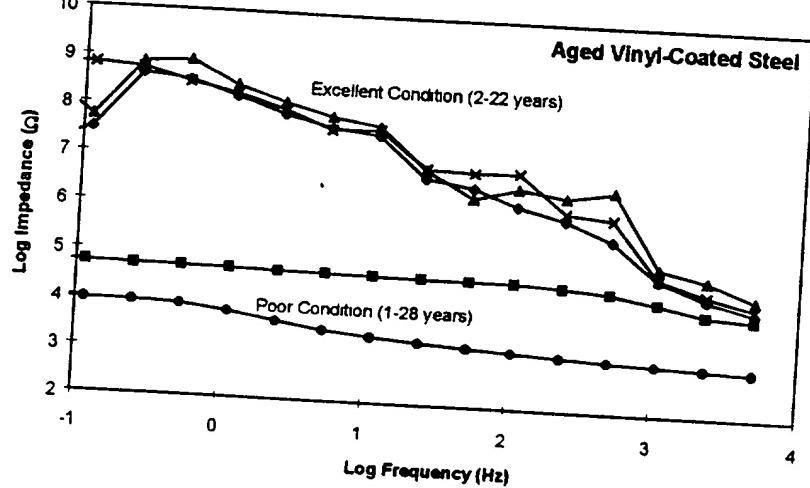
FIGURE 3



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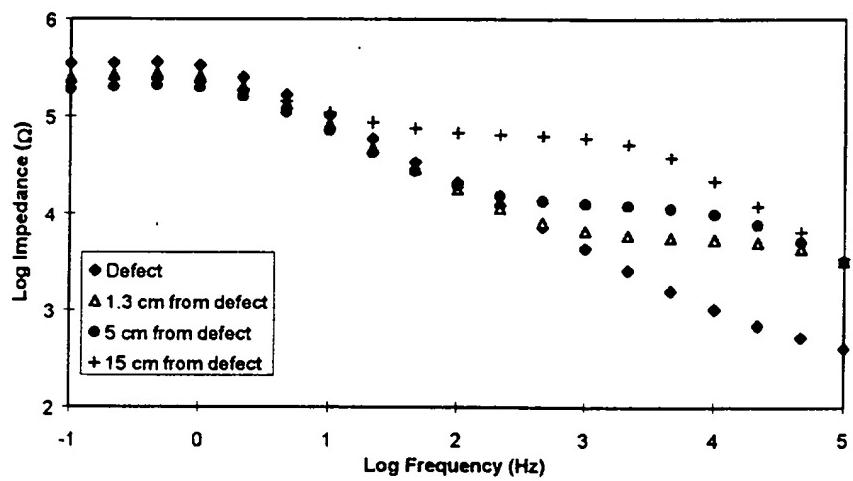
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FIGURE 4

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FIGURE 5

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VERIFIED STATEMENT CLAIMING SMALL BUSINESS CONCERN
(37 CFR 1.9(f) & 1.27(c))—SMALL BUSINESS CONCERN

Applicant or Patentee: Dr. Chester M. Dacres

Serial or Patent No.: _____

Filed or Issued: June 8, 1998

Title: Portable Hand-held In-situ Electrochemical Sensor for Evaluating Corrosion and Adhesion on Coated and Uncoated Metal Structures

I hereby declare that I am:

- the owner of the small business concern identified below;
 an official of the small business concern empowered to act on behalf of the concern identified below;

NAME OF SMALL BUSINESS CONCERN DACCO SCI, INC.

ADDRESS OF SMALL BUSINESS CONCERN 10260 Old Columbia Road
Columbia, MD 21046

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.12 and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees to the United States Patent and Trademark Office, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention described in:

- the specification filed herewith with title as listed above.
 the application identified above.
 the patent identified above.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights in the invention must file separate verified statements swearing to their status as small entities, and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization having any rights in the invention is listed below:

- no such person, concern, or organization exists.
 each such person, concern or organization is listed below.
Dr. Guy D. Davis

Separate verified statements are required from each named person, concern or organization having rights to the invention swearing to their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.22(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Dr. Chester M. Dacres

TITLE OF PERSON IF OTHER THAN OWNER President

ADDRESS OF PERSON SIGNING 10260 Old Columbia Road, Columbia, MD 21046

SIGNATURE Dr. Chester M. Dacres DATE June 8, 1998

**VERIFIED STATEMENT CLAIMING SMALL ENTITY STATUS
(37 CFR 1.9(f) & 1.27(b))—INDEPENDENT INVENTOR**

Docket Number (Optional)

Applicant or Patentee: Dr. Chester M. Dacres

Serial or Patent No.: _____

Filed or Issued: _____

Title: Portable Hand-held In-situ Electrochemical Sensor for Evaluating Corrosion and Adhesion on Coated and Uncoated Metal Structures

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office described in:

- the specification filed herewith with title as listed above.
- the application identified above.
- the patent identified above.

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

- No such person, concern, or organization exists.
- Each such person, concern or organization is listed below.

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

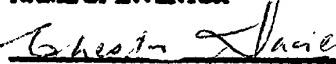
I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Dr. Guy D. Davis
NAME OF INVENTOR


Signature of Inventor
June 8, 1998
Date

Dr. Chester M. Dacres
NAME OF INVENTOR


Signature of Inventor
June 8, 1998
Date

NAME OF INVENTOR

Signature of Inventor
Date

DECLARATION FOR PATENT APPLICATION

U.S. GOVERNMENT PRINTING OFFICE: U.S. DEPARTMENT OF COMMERCE

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled Portable Hand-held In-situ Electrochemical Sensor for Evaluating Corrosion and Adhesion on Coated and Uncoated Metal Structures, the specification of which is attached hereto unless the following box is checked:

was filed on June 8, 1998 as United States Application Number or PCT International Application Number _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Claimed

Yes No

Yes No

Yes No

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

(Application Number)	(Filing Date)	(Status - patented, pending, abandoned)
(Application Number)	(Filing Date)	(Status - patented, pending, abandoned)

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Address all telephone calls to Dr. Chester M. Dacres at telephone number 301-596-3819
Address all correspondence to Same

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor (given name, family name) Dr. Guy D. Davis

Inventor's signature Guy D. Davis Date June 8, 1998

Residence 1 S. Beechwood Avenue Citizenship U.S.A.

Post Office Address Baltimore, MD 21228

Full name of second joint inventor, if any (given name, family name) Dr. Chester M. Dacres

Second Inventor's signature Chester M. Dacres Date June 8, 1998

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Additional inventors are being named on separately numbered sheets attached hereto.